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A RARE HALO AT QUEBEC

By W. E. Knowles Middleton

FIGURE 1 is reproduced from a drawing of an unusually complex halo observed on December 21, 1934, by Mr. Maurice Royer, the Superintendent of the Observatory at Quebec. In this phenomenon, besides the fairly common circular halo (no. 7 in the figure) with a radius of about 22°, there is the much rarer 46° circle (8), the paraselenic circle parallel to the horizon (1), and three sets of bright spots on it at angles of about 22°, 46°, and 134° from the moon on each side (2, 3, and 4). These are known as paraselenae, or more commonly as "moon-dogs" or "mock-moons". The pillar, a vertical streak (5) through the moon, produced further bright spots at its intersections with the 22° and 46° circles. These bright spots, acting as secondary sources, apparently gave rise to the short horizontal arcs (6), which are analogous to the paraselenic circle.

In addition to all these, three tangent arcs (9,10, and 11), not parts of circles, were observed, of which one the supralateral tangent arc of the 46° halo (11), is extremely rare. According to Pernter and Exner* this arc had (in 1922) been reported only once.

The paraselenae of 134° (4) seem to be even rarer, as they are not mentioned at all in the comprehensive treatise of Pernter and Exner, though Humphreys† refers to the possibility of their formation.

*Pernter, J. M., and F. M. Exner, *Meteorologische Optik*, 2nd ed. partly revised by F. M. Exner, Leipzig, 1922, W. Braumüller. Page 409.

†Humphreys, W. J., *Physics of the Air*, 2nd ed., New York 1929, McGraw-Hill. Page 524.

It may be well to summarize the eleven separate phenomena which appear on fig. 1.

(1) *Paraselenic circle*—a white circle, parallel to the horizon and at the same elevation as the moon.

(2) *Paraselenae of 22°*

(3) *Paraselenae of 46°*

(4) *Paraselenae of 134°*

The paraselenae mentioned in (2), (3), (4), are bright spots on the paraselenic circle at the given angles from the moon.

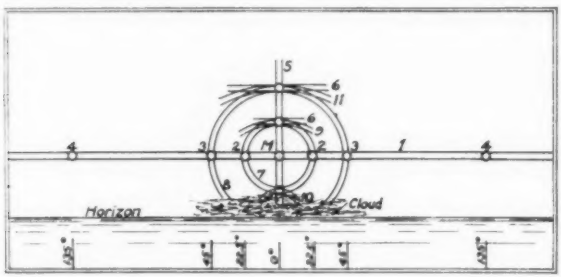


Fig. 1.—Lunar Halo-complex observed at Quebec by Mr. Maurice Royer on December 21, 1934, 18 h.—21 h. E.S.T. The moon is designated by *M*.

(5) *Moon-pillar*—a vertical streak through the moon.

(6) *Secondary horizontal arcs*—arcs parallel to the horizon through the intersections of the moon-pillar and the 22° and 46° halos.

(7) *Halo of 22°*—a coloured circle of about 22° radius, with the moon as centre.

(8) *Halo of 46°*—a coloured circle of about 46° radius, with the moon as centre. (This circle, and no. 7, sometimes fail to show colours when they are faint.)

(9) *Upper tangent arc of the 22° halo*

(10) *Lower tangent arc of the 22° halo*

(11) *Supralateral tangent arc of the 46° halo.*

The arcs mentioned in (9), (10), (11), which are tangent to the

halos named, are not parts of circles. Their form varies greatly wtih the elevation of the moon.

Halos similar to all these might be produced about the sun. In that event, the horizontal circle (1) would be called the parhelic circle, and the bright spots on it parhelia, "sun-dogs", or "mock-suns".

All these beautiful phenomena, and many others of the same general type, are due to the refraction and reflection of light by immense numbers of tiny ice crystals floating in the atmosphere. By applying the laws of optics, physicists have been able to calculate the light paths which will produce nearly all the observed phenomena; and conversely we can infer from measurements on halos the shapes and attitudes of the floating ice-crystals.

Mr. Royer is to be congratulated on his initiative and care in observing this phenomenon. The Director of the Meteorological Service of Canada, Toronto, will welcome observations and sketches of optical phenomena in the atmosphere. Such occurrences are by no means rare in Canada.

Meteorological Office, Toronto,
March 21, 1935.

SIMON NEWCOMB—HIS CONTRIBUTIONS TO MATHEMATICS AND ASTRONOMY*

By A. F. C. Stevenson

THIS year marks the centenary of the birth of Simon Newcomb, the distinguished American astronomer. Born in the village of Wallace, Nova Scotia, and spending his boyhood in this country, career is of more than usual interest to Canadians.

His ancestors appear to have been mainly artisans or minor professional people, intelligent, but with no great education. His father was a country schoolmaster, which in those pioneering days was almost a nomadic profession in the United States, a teacher seldom remaining for more than a year or two in one place before moving on to try his luck somewhere else. Simon was a precocious child, and early in life displayed an interest in Mathematics and Astronomy; but, strange to say, he received almost no formal education, being indeed almost entirely self-taught.

At the age of sixteen he paid a visit to his grandfather in Moncton, N.B., and almost by chance became apprenticed to a doctor who practised in a neighbouring village. Although Newcomb had no special taste for medicine, this appeared to him to be an opportunity to enter the world of culture and enlightenment, and he eagerly accepted. He was doomed to disappointment, however. The doctor turned out to be a quack with no knowledge of medicine and no desire to teach the boy anything, even if he could, merely using him as a cheap and handy man-of-all-work. Opportunities for study of any kind were also few, but he did what he could with a few borrowed books on chemistry and the classics.

It became apparent that this employment could only lead to a blind alley, and eventually, at the age of eighteen, he decided to run away. With practically no money in his pocket, he walked all the way to St. John, a distance of eighty miles, in two days, spending the night at a hospitable farmhouse on the way. In St. John, he came

*From an address delivered to the Toronto meeting of the Royal Astronomical Society of Canada on March 12, 1935.

close to destitution, but just managed to eke out a bare existence. After a week, he contracted with the captain of a small sailing vessel to take him to Salem, Mass., in return for his services and the very little money he had left.

He now obtained employment as a country school-teacher in Maryland, and subsequently as a tutor in the family of a planter who lived near Washington. His nearness to Washington made it possible for him to pay many visits to the capital, during which he made the acquaintance of several scientists, including Professor Henry of the Smithsonian Institution, for whom he conceived a warm affection. It was in the library of the Smithsonian Institution that he first set eyes on Laplace's classical treatise on celestial mechanics, the subject which was subsequently to be his special field of work. The very name "celestial mechanics" has a kind of romantic flavour about it which must have fascinated many budding mathematicians and astronomers, though their ardour may have cooled somewhat on closer acquaintance, for celestial mechanics is a very complex subject. Laplace's style is particularly difficult and Newcomb once remarked that when Laplace prefaced a remark with the words "it is obvious that", he knew he had several hours of hard study ahead of him to find out what was meant!

By this time Newcomb had made up his mind that mathematics and astronomy should be for him his life's work, and he commenced his astronomical career in 1857 when he succeeded in securing employment as a computer in the United States "Nautical Almanac" office, then at Cambridge, Mass. This was for him the gateway to his heart's desire; in his own words it was "the entry into the world of sweetness and light from the world of cold and darkness."

Newcomb's duties as a computer left him leisure for continuing his studies, and he enrolled as a student of the Lawrence Scientific School of Harvard University, graduating with the degree of Bachelor of Science in 1858. His contributions to mathematics and astronomy commenced at this time, and continued in an unbroken stream till the time of his death.

In 1861 he was appointed professor of mathematics in the United States Navy for service in the Naval Observatory at Washington, and in 1877 to the directorship of the Nautical Almanac office which

had by then been moved to the capital. In 1884 he was further appointed professor of mathematics at Johns Hopkins University, holding this position in addition to the directorship of the Nautical Almanac office.

Newcomb's contributions to both the theoretical and observational sides of astronomy were many and various, but it is for his work in celestial mechanics that he is best known. Although the foundations of that science had been well and truly laid by Newton, Laplace, and others, the existing calculations of the motions of the planets and satellites of the solar system were by no means adequate, and Newcomb set himself the stupendous task of pushing the calculations—with, of course, the assistance of others—to such an extent that they should adequately represent the motions over a long period of time; at the same time, he sought by every means possible to increase the accuracy of the observations.

The mathematical problem of determining the motions of any number of bodies under their mutual attractions has never been solved if the number of bodies exceeds two. But in the case of the solar system, the fact that the sun's mass is much greater than that of the other bodies (or, in the case of satellites, that the distance from their primaries is relatively small) enables approximate methods to be used, each body being regarded as moving in an ellipse of the two-body problem, the "elements" of this ellipse—*i.e.*, the quantities which define its size and orientation in space— changing slowly due to the perturbations of the other bodies.

Many of Newcomb's calculations of planetary orbits and of fundamental astronomical constants, such as the constant of precession, are in use at the present time. One of his investigations is of particular interest to-day, namely, that relating to the revolution of the perihelion of Mercury, this being the only planet for which the agreement between theory and observation was not satisfactory. Newcomb laboriously investigated all possible causes of the discrepancy, including the hypothetical existence of an intra-Mercurial planet, but came to the conclusion that no satisfactory explanation could be offered. The discrepancy remained unexplained till 1917, when Einstein showed that the general theory of relativity required a small revolution of perihelion to be superposed on the Newtonian motion;

the correction is inappreciable except in the case of Mercury, for which it gives almost exactly that required by observation; this result constitutes one of the main experimental verifications of Einstein's theory, and the possibility of making the agreement so precise depends very essentially on the painstaking theoretical and observational work performed by Newcomb and his assistants.

One of his assistants at Washington was G. W. Hill, whose work in the lunar theory easily ranks him as the greatest worker in dynamical astronomy this continent has yet produced, and to whom Newcomb paid generous tribute. The lunar theory, it may be remarked, is particularly difficult on account of the large perturbations caused by the sun, and Hill developed original methods for dealing with the problem.

Although the work of Newcomb and other mathematical astronomers enables us to predict with considerable confidence the motions of the bodies composing the solar system for probably thousands of years, we are still in the dark as to what will happen in the far distant future, for the methods of approximation used are only valid over a limited period of time on account of the occurrence of so-called "secular" terms. In particular, the very interesting question as to whether or not the solar system is "stable"—*i.e.*, whether things will continue much as at present, or whether there will be progressively greater changes—is left unanswered, though there is no doubt that the system is stable over a considerable period of time.

In trying to predict what will ultimately happen, however, other factors have to be taken into account. In the first place, the bodies are not in reality rigid bodies as is assumed in the ordinary treatment, but possess a certain degree of fluidity. This gives rise to a phenomenon known as "tidal friction" which tends to enlarge the distance between the bodies of a two-body problem and at the same time to cause them always to turn the same face to each other; it is for this reason that the moon always turns the same face to the earth, and that the earth will eventually do the same to the moon, the terrestrial day being thereby much lengthened. When all the bodies of the solar system are taken into account, the ultimate state predicted is one in which they will all turn the same face to each other; there

will then be perpetual day on one half of the earth and perpetual night on the other.

But there is another factor to be reckoned with, whose effect is even slower than that of tidal friction, namely, loss of mass by radiation. The sun is, according to modern theories, losing mass continually—only in this way can it keep up its enormous outpouring of energy—and there is a similar, though very much smaller, loss of mass going on in the earth and probably in all the planets and satellites. This continual loss of mass means an ever-increasing distance between the bodies. It thus appears that the solar system is ultimately due for radical changes, and that consequently it is to be regarded as unstable, even though it should prove to be stable according to calculations which neglect these factors.

Newcomb's contributions to mathematics apart from astronomy were somewhat restricted, mainly in the theory of probability and in geometry, but it is evident he was an accomplished mathematician. His interests were by no means confined to his chosen science. He was much interested in economics, and achieved quite a reputation as an economist; he was one of the first to apply mathematical principles to that subject. He had the gift of expounding astronomy in popular terms to the general public, and his books were widely read and translated into many languages.

He died in 1909, being survived by his widow and three daughters. In disposition, he was singularly honest and straightforward, disliking any kind of sham or pretence and steadfastly seeking the truth in all things. He often appeared to be too cold and dispassionate to his assistants, but this was merely a cloak for his warm nature underneath. His was a strong and rugged personality. His contributions to celestial mechanics and astronomy in general won him universal recogntion and many honours and assure him of a place among the great astronomers of the last century.

Department of Applied Mathematics,
University of Toronto.

THE ROMANCE OF VENUS

By William Gifford Hale

EVER since lovers first gazed upon the star of evening and wove romances about it and the goddess of love it represented, men have wondered what it was, how far away, and why it appeared first on one side of the sun as the evening star and then on the other side as the morning star.

With the progress of the ages our knowledge has increased, until we can say definitely that Venus is a world almost as big as the earth, having a diameter of 7,600 miles, as against earth's 7,963; that it revolves round the solar orb as does our world, but in a smaller orbit, inside ours, in a period of eight months, and once in a while passes directly between us and the sun, at which time it appears on the sun's disc as a small black round spot,—which passage is called a transit.

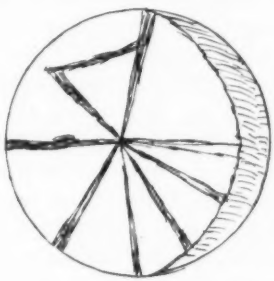
As to its physical condition, opinions are as diverse as the poles, observations of markings upon its surface being no sooner made and announced than they are contradicted by someone else. Probably the first and earliest astronomer to attempt a map of this sister world of ours was Bianchini, away back in the 17th century, who drew a map of two similar continents, on opposite sides of Venus, and concluded that its rotation upon its axis was much slower than ours, as much as several days in length. Other observers, seeing that Venus showed to them practically the same markings every day, jumped at the conclusion that it revolved in identical time to earth. Neither to them nor to Bianchini did it occur that perhaps the two similar continents on opposite sides were really the same one, and that Venus kept the same side to the sun all the time, so that whenever they saw its illuminated portion they were really gazing upon the same side.

It took the sharp eyes of another Italian, observing in the crystal-clear skies of Milan, to discover this. He had been watching Venus and Mercury for assiduous months, and having startled the scientific world by averring that Mercury did not spin, except just once as it encircled the sun once, he followed this by a similar sensational

statement about Venus. This mysterious planet, he said, just kept the same face to the sun all the time, for having watched it closely for months on end, night after night, whenever its position allowed him to do so, he saw the same markings in the same relative positions. So a too readily received opinion that Venus spun about every 24 hours, which had passed current for two centuries, was upset. At once wits set to work to find out the reason for such cessation of spin, and the only cause seems to be the strong tides caused by the sun upon the oceans and liquid interior of this planet which is but two thirds of our distance from the sun. "Tidal drag," so fervently invoked by Darwin and explained by Ball, had checked the spin and brought one face of this world to a stand as far as the sun was concerned.

Then came Percival Lowell, America's great pioneer of the skies, whose courageous exploration of the celestial spaces and brilliant deductions from it are so far ahead of his times, or rather of the intellectual power of interpretation of the times, that it will take another generation of wonderful progress in science before the world of astronomers does him justice. He devoted his fortune and his life to the splendid adventure of proving that intelligent beings exist on other worlds. He built at his own expense the mountain observatory of Flagstaff in Arizona, and there he spent the last 20 years of his life with a staff of sympathetic enthusiasts whom he drew around him, observing, observing, observing—night after night, and day after day, following the planets Mars, Mercury and Venus even in the daylight sky, when the dazzling silver glare of Venus is toned down by the rival sun. For if you know where to look you can almost always find Venus sometime in the day or night sky. So his results accumulated until at last, just as he had stirred the astronomical world by his insistence of intelligent life on Mars and had mapped out such a maze of "canals" on its surface, so he gave it a second and greater shock by announcing that he had seen, on the dazzlingly bright silver disc of Venus, strange markings—dim but definite—like the spokes of a wheel, that never changed their position but "stayed put" the whole year round. (See adjoining figure.)

Just let us try to realize the strange state of a world like that:— Supposing the earth's spin slowed down through ages and at last stopped, thereafter turning just once upon its axis as it circled the sun once a year. Like a child walking round a table with a lamp upon it, and keeping his face to the lamp all the time, he would have turned round just once as he walked round the table once. If then the earth spun so, like Venus, one hemisphere, say America, would see the sun always overhead, never rising any higher, never setting, but always stock-still in the skies, age after age. And, by the way, to this strange condition our earth may some day come. The antipodes of America, say China and Australia, would in such condition



VENUS, OCTOBER 9, 1896

Rough sketch of Lowell's drawing in his "Evolution of Worlds", reproduced here by kind permission of Messrs. Macmillan Co., New York, N.Y.

never see the sun at all, but always the star-lit sky. So, if you wanted to see the stars, you would have to journey half-way around the world, and select at your will your place of abode, a country where like Tennyson's "Lotus-Land", it was always afternoon, or, if you liked it better, always midday or everlasting night.

On the constantly sunlit side of the world the heat would grow more and more intense, and from its central part there would be a great uprush of steam, carrying with it vast clouds of heated air from the dry lands. High into the upper air it would soar and then blow away in every direction from, say Mexico, to the north, east, south and west. For thousands of miles those lofty winds would blow, roaring onwards, until they reached the dark edges of the

sunlit world. Here they would blow out of sight of the sun, and into the eternal dark and cold of the "night lands." Cold with the absolute zero of the space-world those night-lands would be, and the hot moisture-laden winds would quickly feel the chill; and down would come the rain. Then would commence a rainstorm the like of which the world has never yet seen since the primeval condensing of the oceans from its primitive atmosphere of steam, changing as the wind penetrated farther and farther into the everlasting night, into a blizzard of blinding snow. Age after age upon the cold dark lands the snow would descend, until they would be covered deep in a winding sheet of colossal thickness. One side of the world would be wrapped in an ice sheet that would cover possibly thousands of miles, until all round the edges of the dark side would be piled an enormous ring of mountainous glaciers. Chilled to below zero, the cold wind, robbed of its moisture, would blow back along the ground from the dark to the sunlit side, where it would again gather moisture from the seas and lands there and rush on to the centre of the torrid hemisphere to rise again and blow away with a fresh load of steam, to condense as rain and snow when it again reached the dark side of the world.

Continued for hundreds of years, this process would at last pile up almost all the water of the world upon the dark side in the form of ice and snow, except where, in the border zone, rain fell before the chill had turned the moisture to snow.

Now Shift the Scene to Venus.

Consider now this process completed; what next? To picture our strange sister world of Venus we will transfer ourselves to that mysterious planet, where it seems likely that just such a process has been going on for unaccountable myriads of years. Lowell thought the veil which partly screens the features of Venus was caused by dust storms raised by the winds we have been describing, and that all the water of Venus' oceans had been finally fixed on the dark side in the form of ice and snow.

But comes now a notable English astronomer, Housden by name, who cleverly interprets the real meaning of those queer spoke-like markings of Lowell's map. The veil of Venus, he says, is not one

of dust but of steam clouds, rising from the heated but not altogether dried-up lands of our neighbour world.

Swinging Into the Sunshine.

For here comes in the strangest factor, and it seems to give us the key to the whole mystery. Although Venus keeps the same face to the sun practically all the time, yet there happens every four months a slight change in the way she does it, for the spin varies in a way called libration, which brings a hundred miles of territory from the dark side forward into the sunshine for a month, and then swings that side back into the night again while the other side swings forward in turn. It is as if the ice-laden lands we have been picturing saw the sun rise just a few degrees above the horizon, hang there for a month, and then slowly set again. What would happen? Remember that the sun, as seen from Venus, is twice as big to look at, and twice as hot, as it is to us here on earth, for Venus is thirty millions of miles nearer to the sun than we are. Picture then, if you can, a vast glacier range of mountains of ice and snow, miles high, receiving the torrid heat of a super-tropical sunrise.

Although the sun would not rise very high, yet it would be plenty high enough to start a tumulous melting of the ice mountains and a rushing of icy waters in a torrential flood out over the sunlit lands of Venus.

For a whole month this flood would pour its waters out over the parched lands, and then slowly the sun would sink and set, and over the border zone would settle again the snowy chill and storms of the arctic night.

That then, is Venus, as Lowell drew it, and as we have imagined it.

It is a great world of two great zones or hemispheres; an arctic side, mostly wrapped in snow and ice, a bitter polar waste which never sees the day; and a tropic side which is everlastingly exposed to a sun twice as big and hot as he is in Central Africa, one too cold and the other too hot for comfortable living. Between the two is a great land belt surrounding the entire planet, a thousand miles wide and 20,000 miles long, a country neither too hot nor too cold for habitation! There the sun is always low in the sky, and temperate

is its light and heat. A stretch of country 20,000 miles long by 1,000 miles wide makes 20,000,000 square miles of habitable land, supplied from behind with unlimited supplies of ice-cold water, and cooled always by the cold dry winds blowing back along the ground from the dark to the light side of Venus.

Is it not possible that men could live and thrive there, grow all the crops they wanted, and develop all the arts of a splendid civilization? Or to put it another way, suppose they realized that theirs was the only part of their world on which life could be comfortably maintained, would they not be fools not to stay and make the best of it? Probably nothing of the sort would ever enter their heads; but if they ever travelled round to the dark side of their planet to study the skies they would see a great green star, shining in the night sky, with a little white one keeping it company. Those two stars are the earth and the moon, as they appear to dwellers on Venus. They would most likely wonder how intelligent life could maintain itself on a world whirling around every 24 hours, and have enough water reserve to keep it going.

Now let us see what Lowell's map, with its spoke-like markings means:

Look again at his rough sketch of the sunlit side of Venus—the only side we can ever see to map. From the edge of the dark side where the great ice-floods would start, stretch out far into the tropic lands long tapering dark markings. Take it that they are valleys down which the waters flow from the melting glaciers and the border-zero rains. What more probable than that they contain broad stretches of irrigated land, dark with evergrowing crops? For remember on Venus there is no winter.

About 500 miles wide at first, as scaled from Lowell's drawings, they start with a full supply of water nearest the cool country, where all kinds of crops could be grown, and where the water supply was most plentiful, they gradually narrow as they run farther into the super-tropical sunshine, where only equatorial plants could survive, and nearly vanish away in the central desert inferno of that terrible vertical sun.

The rapid evaporation of the water under such a sun would keep the air filled with steam, and just such white clouds as this would

cause may now continually veil the face of Venus. No doubt, too, this screen of vapour will serve to temper the fierce rays of that terrible sun. We see "through a glass darkly," or rather as through a silver veil which reflects the sunlight in a dazzling sheen, those elusive markings of Venus, and only here and there does anything show through.

A great crescentic range of mountains seems to rise clear above the clouds around the south pole, and at several points around the edge of the sunlit hemisphere tower enormous isolated peaks of vastly greater proportions than earth's highest peaks and summits, seeming even as lofty as twenty miles above the steam-veiled lands below.

So we may picture this nearest sister world of ours in space as a romantic globe that has long since ceased to spin, but which shows the most evident signs of the intelligent activity of a very highly civilized race of beings. For the inhabitants of Venus seem to have solved the problem of how to live and thrive on a planet which has an arctic waste on one side and a fiery desert on the other, with a strip of temperate land between.

The Ghostly Gleam of Icy Deserts.

A final thrill is given us as we hear that many astronomers have seen a weird effect when Venus comes between us and the sun and when consequently we are gazing at the dark arctic side of Venus. Then, instead of the absolute blackness of the eternal night of that sun-less country they see a strange ghostly grey gleam, as of star-light reflected from the vast white snowfields of a frozen world.

May we not look to the future to reveal more of this wonderful world by advance in photography, by the use of the spectroscope, and even by other unknown means, in addition to the ordinary telescope work of the astronomer?

Newest Ideas.

Recently several new and interesting investigations have been conducted, which furnish us with more food for thought about Venus. Most important of these is the amount of heat emitted from the dark side of Venus, as registered by the thermo-couple.

This seems to prove that some sensible heat is after all emitted

from the supposedly frozen surface. If this turns out to be true it may set us again picturing fresh conditions, for much heat would indicate a faster rotation than the 8-month term, unless indeed, the warm winds blowing over from the hot side to the cold one carry so much heat as to sensibly moderate the arctic character of the "dark lands."

Then there is the well-known fact that the edge of the sunlit disc is even more brilliantly white than the more central portions. This would indicate the presence there of either denser white cloud-banks or broad tracts of snow-covered lands. Perhaps the ice-mountains spoken of above may extend permanently out farther into the sunlit lands than we have been supposing, much as they do in our own arctic regions. This would still further strengthen our idea of great ice reserves available for periodical melting when libration carried them farther out into the sunshine.

Lastly, there is W. H. Pickering's suggestion that Venus, after all, rotates like Uranus, at almost right angles to its supposed vertical spin. He founded this idea upon his observations of certain spots that appeared to move vertically downward across the disc, as if the axis of revolution is almost in the plane of the orbit. But this seems unsupported by any later observations.

Seattle Astronomical Society,
Seattle, Washington, U.S.A.

WHEN YOU HAVE FINISHED YOUR TELESCOPE—WHAT NEXT?

Hints on Variable Star Observing

By D. W. Rosebrugh

As a result of the activity of the *Scientific American* in promoting amateur telescope making it is believed that several thousand telescopes have been constructed by amateur astronomers. In addition many used refractors have changed hands at relatively low prices because of the economic depression. In this way many astronomical votaries find themselves equipped with relatively powerful instruments.

The first act of the new owner of a telescope will be to give it a comprehensive test,—first doubtless on the moon and then, breathless with anxiety, on a double star, perhaps Epsilon Lyrae if the instrument is small or Zeta Bootis if the instrument is large. Thereafter many delightful evenings of browsing among the stars and planets await the zealot and his friends. The rings of Saturn, the Ring Nebula of Lyra and the Star Cluster in Hercules become old and trusty friends. Oh to capture again "the first fine careless rapture" of these sights! But alas! the novelty soon palls. The amateur finds that he can contribute little or nothing new to the science by these sporadic observations, and the telescope soon languishes in the cellar or attic and the stars have lost their devotee.

It is at this time that one should join the American Association of Variable Star Observers by applying to Dr. Helen S. Hogg, David Dunlap Observatory, Richmond Hill, Ontario, or to Mr. Leon Campbell, Harvard College Observatory, Cambridge, Massachusetts.

To a variable star observer the sky becomes alive, the stars call every clear night, they shift, they vary, they change. Those who live among great mountains, or by the sea, or on the plains, know that nature is ever changing. A gust blows, or a mist comes, the sky is blue or it is grey,—in the presence of nature no one can feel alone. To the city dweller variable stars give this same sense of warm companionship with nature.

The term "variable star" is familiar to the readers of this

JOURNAL. It is not the purpose of this article to discuss the physics of variable stars but rather to describe how to observe them. However a brief outline of the types of variable stars may well serve as an introduction. The great majority of the stars in the sky are substantially constant in brightness, but several thousand of them, mostly faint, are known to vary in brightness through one or several magnitudes.

The simplest type of variable is the class of eclipsing variables, like Algol. Once the period of such a variable is determined, as the period of the remarkable star Zeta Aurigae was determined last fall, constant observations of a star of this type are not necessary. This comment also applies to some extent to stars of the Delta Cepheid type.

But there are many other types of variables, the causes for which are not known. Most interesting of course are novae, such as Nova Herculis 1934, stars which are ordinarily faint but attain great brightness once in a nage, or as RS (Nova) Ophiuchi, which rebrightened in 1933, decades after its first recorded outburst in 1898. But what are the causes of the irregularities in SS Cygni and U Geminorum, ordinarily of the 12th and 14th magnitudes but brightening frequently but irregularly to the 8th or 9th; or of R Coronae Borealis, ordinarily of the 6th magnitude but now of about the 9th, for the first time in ten years; or of Omicron Ceti, which varies with some semblance of regularity from the 3rd to the 9th magnitude but whose actions can never be exactly predicted?

Professional astronomers cannot afford to devote their time or instruments to following these variable stars, except when they are unusually active as the nova in Hercules or R Coronae Borealis are at present, and the engrossing task of accumulating data upon them is left to the amateur,—hence the A.A.V.S.O.

Having applied for membership in the A.A.V.S.O. one will be sent charts of a few variables upon which to try one's skill before admission. These maps are of four kinds. The "a" charts cover about 15 degrees square of the sky and are good for naked eye variables or for variables down to perhaps the 7th magnitude which one will ordinarily observe by eye or with field glasses or binoculars. The "b" charts are about 3 degrees square and are used for stars of about the 7th to the 10th magnitude or for variables of wide range

when they become too faint for the "a" chart to be useful. A 2-inch finder or 3-inch telescope will be found very convenient for stars in this range of brightness. The "d" charts are 1 degree square and deal with stars of the 10th to the 15th magnitude, or with variables when they have become too faint for either the "a" or "b" charts to be useful in observing them. From 3-inch to 15-inch telescopes are required for such stars but a 6-inch telescope will suffice down to the 12th or 13th magnitude. The fourth type of chart is the "finder" chart which is useful in locating the variable for which one is searching with the telescope finder as it shows many naked-eye stars.

The particular variable star for which a set of charts is drawn is located in the center of the "a," "b" and "d" charts and its magnitude is determined by the Argelander method, *i.e.*, the magnitudes of many comparison stars which are thought to be constant in brightness are shown on each chart and the variable is compared with these stars. For instance a variable fainter than 9.2, 9.5 and 9.8 but brighter than 10.6 and 10.2 is probably about the 10.0 magnitude.

For some stars with wide range "a," "b," "d" and even "e" charts are issued, while on many stars which never become very bright only a "d" chart and a finder map are available.

Full details as to how to make and report observations will be sent applicants for membership by the A.A.V.S.O. and more star maps may be purchased at nominal prices later on. This article will not repeat these instructions but will be devoted to the technique of observing as developed by the actual experience of an amateur.

At this point let us give summaries of the essential, non-essential and desirable equipment and conditions for the variable star observer, together with brief explanations and comments on each point.

The essential things for one who plans to observe stars of the 9th magnitude or fainter are as follows:

(a) Sets of charts for one or more variable stars as furnished by the A.A.V.S.O., not forgetting the finder charts for each variable, which should be glued on the back of the "d" or "b" chart.

(b) Enough knowledge of the constellations so that with a Norton's Star Atlas one can locate the naked eye star nearest to the variable.

(c) Clear sky without haze. Unless the variable is bright and the field is very familiar it will be found difficult, if not impossible,

to locate the star and make a satisfactory observation unless the sky is say 90% free from clouds and is free from haze, especially in the winter if the moon is nearly full.

(d) A small pocket flashlight with which to scan the star chart from time to time while seated at the telescope. While at the eyepiece, the star map is most conveniently held in the left hand for ready reference, and the right eye should be shut when consulting the star chart so that it will not be left blinded by the flashlight.

(e) A telescope of three inches aperture or more. This should have a wide-angle inverting finder of not less than one inch aperture for a 3-inch telescope or two inches for a 6-inch telescope and larger. An ordinary terrestrial draw-tube telescope will be found satisfactory if the erecting lenses are removed. The main telescope itself should be inverting and should be equipped with an eyepiece having as wide an angle as possible, and having not more than 10 or 15 power per inch of aperture for refractors or 8 or 10 power for reflectors. The telescope should preferably be mounted equatorially, but only approximate adjustment of the polar axis is necessary. The only merit of the equatorial mounting is that it is a little easier to follow the star when once it is located. Slow motion screws and setting circles are quite unnecessary as it will be found in practice that all movements are made by hand. The mounting should be tolerably free from vibration and especially from "lost motion" so that it will stay in place when once pointed. Dew caps of blotting paper for the objectives of finder and of refracting telescopes are essential, and a dew cap may be necessary on the end of a reflector to protect the prism or secondary mirror from dew. Dew caps should extend forward one or two diameters of the tube.

Binoculars may be used in observing variables down to the 7th or 8th magnitude. 3-inch telescopes will work down to the 11.5 magnitude under favourable circumstances or 10th under unfavourable conditions such as light haze, bright moonlight, or stars near the horizon, while 6-inch telescopes will work down to the 13th magnitude if the stars are near the zenith and it is quite clear, otherwise to perhaps the 11.5 or 12 magnitude.

At this point the relative advantages and disadvantages of the reflector and refractor from the view-point of the amateur may be briefly touched upon. The accompanying illustrations make the rel-

ative advantages of each type almost self-evident. Fig. 1 shows a 12-inch reflector built by the author. His advice after building both 8 and 12-inch reflectors is not to attempt anything above an 8 or 10-inch unless one has unusual facilities for mounting and housing the telescope, for a 12-inch reflector is too large and heavy for ready mounting and manipulation by one person. It is evident that the reflector is well adapted to pointing towards the zenith where the faintest stars can be most readily seen, but it is more difficult to

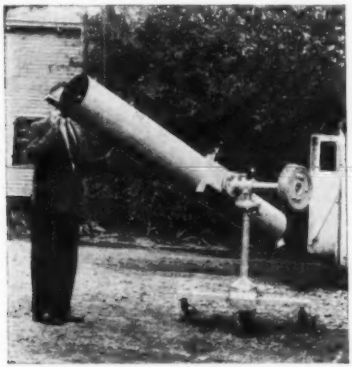


FIG. 1.—HOME MADE 12-INCH REFLECTOR WITH ALT-AZIMUTH MOUNTING OF OLD FORD REAR AXLES, MADE BY THE AUTHOR.

The front end of the finder is visible at the extreme left and the location of the eyepiece is closely adjacent. The convenient position in which the observer can stand is evident, but the difficulty of finding an object is obvious, for the telescope cannot be aimed as a rifle can be. The reflector is especially adapted to observations near the zenith.

point, even with a finder, than is a refractor. The physical position of the observer is comparatively comfortable.

Fig. 2 shows a 6-inch refractor. It is easy to point for one can look along the tube, as with a rifle, but it is awkward to use near the zenith even with a zenith prism, so that it is best used on stars at medium altitudes.

With the new aluminum mirror coatings the reflector is relatively permanent in its light-grasp but of course a refractor is constant in this regard, so that one soon develops a sense of judgment as to the

magnitude of stars seen through it, which is of great aid in locating a variable star, as the description which will presently follow will indicate.

(f) The sixth and last essential for the variable star observer

FIG. 2.—SIX-INCH REFRACTOR WITH EQUATORIAL MOUNTING AND 2-INCH FINDER.

The ease with which this can be pointed to locate stars is obvious, since it can be sighted like a rifle, but the awkward position for the observer is evident, and zenith observations are difficult. The setting circles and slow motions are quite unnecessary in variable star work.

is a pencil and observation sheet for jotting down observations.

The following things are not essential for the observer: setting circles or slow motions on the telescope; any great or specialized knowledge of the constellations,—this will soon come with experience; particularly good eyesight is not necessary, though freedom

from colour blindness is desirable as some variables are quite reddish in colour. The author's eyesight, even with glasses, is so poor that he cannot distinguish the rider, Alcor, in the Big Dipper and can only see four stars in the Pleiades, but when the spherical error in his eyes is fully compensated for by focussing the telescope his eyesight is excellent.

The following equipment is useful but is not essential:

(a) A letter file in which to keep star charts filed by right ascension with a tab every hour or half hour. Loose leaf books for filing charts are an abomination. Charts should be readily available so that they can be picked out and carried to the eyepiece of the telescope.

(b) A box with three different dimensions, such as 9, 12 and 15 inches, on which to sit or stand.

(c) A card index of all stars on which one has charts, with little coloured metal flags which may be moved along the top edge of the card to indicate that the variable may be expected to lie between 8-10, 10-12 or 12-14 magnitudes, will prevent one's wasting time on variables that are beyond the reach of the instrument, considering the "seeing". When one gets into the swing of observing the A.A.V.S.O. will send a bi-monthly prediction sheet giving the anticipated brightness of variables on their list.

Now let us make an observation on a variable star, preferably one not too faint, say perhaps in the 10-12 magnitude zone. While it will be found somewhat harder to locate faint variables it will be found much easier to determine their brightness than that of brighter ones. This is because, once located, all the faint comparison stars needed for estimating a variable of the 11th magnitude are to be found in the one field of view, or with only slight sidewise movements of the telescope, whereas with a bright star, say of the 9th magnitude, the comparison stars are necessarily rather far apart, and in moving the telescope to view them the variable may be lost or the impression of the brightness of the comparison star may be lost in re-locating the variable. And yet these 9th magnitude stars are too faint to see with binoculars, so that all in all they are the most difficult of all variables to observe.

Suppose that we decide to try to locate the variable described on the "d" chart furnished by the A.A.V.S.O. as 043208 RX Tauri.

The number means that the star is located in right ascension 04 hours 32 minutes, declination north 08 degrees. If the number had been 191033 it would have meant right ascension 19 hours 10 minutes, declination 33 degrees south.

The following description of the procedure followed to locate 043208 is a method which the author has found applicable to locating any variable star. Referring to Norton's Star Atlas we find that the point 043208 is about 1h. and 28m. west of Betelgeuse in the upper left hand corner of Orion. If one is not very familiar with the constellations one must first locate Orion and then pick out Betelgeuse. It may be necessary to refer back and forwards several times between the sky and the atlas before one definitely picks out the nearest constellation to a variable. When the constellation Orion is once located we note either in the atlas or in the sky that Gamma Orionis, or Bellatrix, the star in the giant's shoulder to the observer's right, is much nearer to the variable than is Betelgeuse, and we visualize its position in the sky, at the same time making a mental note of a string of several 3rd and 4th magnitude stars running north and south along the west side of Orion's west shoulder. A glance at the atlas shows that these are the stars known as Pi1 to Pi6. Now we are really making progress, for on our finder chart for 043208 we note the stars Pi3 and Pi5 and the bright star between them is evidently Pi4 although it is not labelled. Another look at the sky confirms our diagnosis and we are ready to point the finder of the telescope at Pi3 which is evidently the nearest of the fairly bright stars to the variable 043208. To be sure that we have Pi3 in the finder we run the finder up and down the string Pi3 to Pi5, noting the fainter stars surrounding them and checking with the finder map until we are sure that Pi3 is the star we have in the finder field. The finder chart shows us that 043208 is a little to the north and a little further to the west than Pi3, and not far from what appears to be a tolerably bright star, shown both in the atlas and on the finder chart, although it is not given a name on either. A very little manipulation of the telescope suffices to pick up this star of the 5.6 magnitude in the finder, which we confirm by noting that it is at the 90°-angle of a very small triangle of stars more readily visible in the big telescope than in the finder. We now look at our "d" chart for 043208 and try to visualize what our large

telescope will show us in the sky, picking out the brighter stars in and around the variable by their numbered magnitudes on the "d" chart. Not far from the 5.6 magnitude star which we now have clearly in view in the telescope we note a keystone of stars, lying on its side and surrounding the variable. These are of the 7.5, 8.7, 9.3 and perhaps the 9th magnitude, though the fourth one is not labelled and we can only judge its brightness by its size on the chart. Sure enough a minute motion of the telescope enables us to pick up the "keystone" which is really quite brilliant and easily identifiable, and there, just at the limit of vision, so faint that we have to check back and forward between the sky and the chart is the object of our long quest, the variable RX Tauri! We compare RX with the nearby star of 12.0 magnitude and RX is fainter, we compare RX with 12.9 and it is brighter, it is brighter even than 12.8 but not much. Our final estimate is that it is 25% of the way between 12.8 and 12.0 and we accordingly write it down as 12.6 and our first observation is made!

All this sounds difficult and slow, and it is difficult the first time. The author's log shows that he searched unsuccessfully for this star for an hour the first time he tried to find it, but then it was only the third variable for which he had searched and that was before the A.A.V.S.O. finder maps were available. Now the writer could locate this star within thirty seconds without any maps at all and would have an observation made within three or four minutes at most.

But you say, "Cannot I save all this bother by the use of setting circles?" The answer as found by the author is "No." His unsuccessful hunt of an hour was with setting circles, his successful hunting for all variables since then has been by the method outlined above. The trouble with setting circles as far as the amateur is concerned is that his mounting is seldom permanent and his circles may not be exactly accurate. A good-sized telescope has a field of only half a degree and unless one's telescope is very accurately mounted with axes at exact right angles one cannot readily point the telescope by using setting circles closer than that, so that, even after corrections for precession and sidereal time are all carefully allowed for it is improbable that the variable will be right in the field of view of the telescope or even around its edge. If this is the case one will be forced to identify the variable by the background (or

foreground) of brighter stars such as Pi3, 5.6, 7.5, 8.7 and 9.3 anyway, so that one might as well locate the variable in this way in the first place and save much reading of circles, watching of clocks and calculations of precession.

It is admitted that some stars remote from the nearest 6th or 7th magnitude star are sometimes hard to locate by the above method, but variables near bright stars are very easy to locate. By the above method one can locate and observe an absolutely new variable in from five to twenty minutes, depending upon circumstances. Thereafter the time is much reduced.

Experience will soon teach the observer as to how bright a star may be expected to appear in the finder or telescope and as to how far apart stars on the charts will appear in the telescope field and once one has acquired this sense of judgment with regard to one's own equipment observing will be easier.

Variable star observers should subscribe to *Popular Astronomy* which reports the observations of the A.A.V.S.O. members every month. By comparing one's own observations with those of others one can check the correctness of one's eyes. No two eyes see exactly alike and it will be found occasionally that a 9.2 magnitude comparison star seems as bright or brighter than one marked 9.0. This may represent a difference of opinion between one's eyes and those of the original maker of the chart, or may indeed represent some slight degree of inconstancy in the comparison stars themselves.

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FIVE GREAT GREEK ASTRONOMERS
(c. 408 B.C.—c. 165 A.D.)

By A. Willard Turner

(*Concluded from page 166*)

IV. Hipparchus (c. 180 B.C.—c. 125 B.C.)

We shall now consider an astronomer whose name must be familiar to most students of astronomy. Our subject is none other than the great Hipparchus of Rhodes and Alexandria, who lived from c. 180 B.C. to c. 125 B.C.

Although Eudoxus, Heraclides, and Aristarchus were brilliant and outstanding astronomers, they can scarcely be regarded as the leading personalities of their respective times. Possibly we may attribute much of their comparative obscurity to this fact. Our fourth astronomer, however, was the dominating figure of his time. Thus, while Eudoxus flourished in the time of Plato, Heraclides in the time of Aristotle, and Aristarchus in the times of Euclid and Archimedes, Hipparchus flourished in the time of Hipparchus.

Of his actual writings, an insignificant youthful work[11] is the only complete original text we have. However, his doctrines were carefully recorded and preserved by Ptolemy in his classical treatise, the *Almagest*.

While we are especially concerned with Hipparchus as an astronomer, he enjoyed an enviable reputation as mathematician and geographer. The science of trigonometry (in so far as it is an adjunct to astronomical calculation), and stereographic projection both owe their invention to him. He used the latter device to represent the projection of the celestial sphere upon the plane of the equator. In geography, he originated the present system of coordinates, whereby terrestrial positions are indicated by circles of latitude and longitude.

Hipparchus was responsible for many improvements in the construction of instruments, and was the first Greek observer to divide

circular scales of measurement into 360°, and the first known to construct a celestial globe.

The earliest star catalogue in the history of astronomy is credited to Hipparchus. While the original was lost, it formed the basic content for Ptolemy's later work, and in the main has been retained in the *Almagest*. It is not improbable that Hipparchus' catalogue was inspired by his detection of a "new star"[12]; whereupon he conceived of the advisability of constructing records of star positions, to assist later astronomers in following pertinent changes. Our information concerning the purpose or reason for this work may be vague, but we do know that his catalogue comprised about 850 fixed stars.

"But the discovery which shows beyond all others that Hipparchus possessed one of the master minds of all time was the detection of that remarkable celestial movement known as the precession of the equinoxes."[13] In addition to the actual discovery that the equinoxes were moving slowly westward relative to the stars, he calculated an actual magnitude for the movement.[14] Hipparchus made his discovery by comparing the lengths of the sidereal and tropical years, and attributing the resultant inequality to the precession of the equinoxes. It is of interest to notice that his observations of the tropical year were made with the gnomon, by means of which he found the dates at which the noonday shadow was longest (or shortest according to the solstice concerned), and so calculated the length of the year from solstice to solstice. The sidereal year, determined by the heliacal rising and setting of the stars,[15] was found to be shorter than the tropical, and the resultant difference was traced to an annual westward motion of the equinox, (modern value 50″). Incidentally the physical cause of the phenomenon of precession was not explained until the time of Newton.

Unfortunately, Hipparchus reverted to a strictly geocentric theory of planetary motion. It may not be wholly unfair to suggest that Aristarchus' heliocentric theory was virtually beyond the imaginative power of Hipparchus. Be that as it may, the long predominance of the geocentric theory and the consequent obscurity of Aristarchus' achievement, are usually attributed to the overwhelming authority attendant upon Hipparchus' reputation for many centuries.

Speculations concerning the "might-have-beens" of scientific history, however futile or absurd, are not without interest. Thus, we might be able to reconstruct the whole story of astronomical development from Hipparchus' time had our astronomer accepted the heliocentric truth accessible to him through Aristarchus' work. Hipparchus' geocentric teachings, promulgated and elaborated by Ptolemy, were tantamount to apodictic law, for they were not subjected to that healthy skepticism and impersonal questioning which scientific progress demands. Certainly the tremendous prestige attached to his doctrines can scarcely be overestimated.

Hipparchus has frequently been called "the father of systematic astronomy", the name being suggested, perhaps, by the remarkably consistent combination of observation and theory which typified his work. Clearly he was no abstract theoretical dreamer, for he held hypotheses rigidly subservient to observed facts. Fortunately he himself was one of the most astute observers of antiquity, and the accuracy of the immense number of observations recorded by him is astonishingly high.

Obviously in Hipparchus we have met an intellectual star of the first magnitude. The horizons of astronomical development have been vastly enhanced and extended through his genius.

V. Claudius Ptolemy (c. 85 A.D.—c. 165 A.D.)

For the two and a half centuries after Hipparchus' time, astronomy was so sadly neglected that Claudius Ptolemy (c. 85 A.D.—c. 165 A.D.) is related to Hipparchus as closely as a contemporary collaborator. Sarton tells us that "it is not possible to study them independently", and that "their fame is inseparable".[16]

Ptolemy's antecedents are quite unknown, though there is no evidence to indicate that he was a descendant of the line of kings named Ptolemy who founded the Alexandrian school. Unfortunately we know very little of his life as an individual, his approximate dates being deduced from the statement that he conducted his observations at Alexandria during the reigns of Hadrian and Antoninus Pius.

Of his writings we are chiefly interested in the treatise *Syntaxis*, generally known by the Arab designation, the *Almagest*. A legitimate parallel may be drawn between Euclid's *Elements* and Ptolemy's

Almagest, for each represented a synthetic, comprehensive, and exhaustive co-ordination in its respective field—the former in geometry, and the latter in astronomy. The *Almagest* enjoyed undisputed authority throughout the Middle Ages, and deserves to be considered one of the most monumental works of the ancients.

In the geographical field, Ptolemy wrote a compendium, *Geographike Syntaxis*, which exerted an influence upon geography comparable to that exerted by the *Almagest* upon astronomy. For the most part this work consisted of tables of latitudes and longitudes. Incidentally, the terms meridians and parallels were used for the first time.

He also wrote on the planisphere, on music, on applied mathematics, on astrology, and possibly on optics.

There are commentators[17] who ascribe the effective invention of trigonometry to Ptolemy, but his original contributions to this subject were few, if any. Even so we are much indebted to him for the summary of theorems known by his time.

One of Ptolemy's chief original contributions to astronomy was the discovery of that periodic perturbation in the moon's orbital motion known as evection, the actual explanation of which did not come until Newton's time.

He compiled a star catalogue of approximately 1030 stars, and doubtless based it upon Hipparchus' observations. Herein are given the stars' latitudes, longitudes, positions in the constellations, and magnitudes. The twenty brightest stars are assigned to the first magnitude, those barely visible to the naked eye to the sixth, and stars falling between these two groups to correspondingly intermediate magnitudes. While Ptolemy's work was substantially an extension of Hipparchus' earlier catalogue, it is possible that the inherent errors were relatively greater, for Ptolemy was a very poor observer compared to Hipparchus. It is of interest that Ptolemy listed six "stella nebulosa",[18] each of which has proved to be either a star cluster or a loose group of stars.

In the *Almagest* Ptolemy gave many forceful and ingenious arguments to show that the earth was of spherical shape; he actually presented the familiar one concerning the disappearance of a ship at sea.

The elaborate theory which he propounded to account for planetary motion is familiar to students of astronomy as the Ptolemaic system.

The traditional metaphysical notions that the circle was the perfect curve for planetary motion, and the earth the central celestial body, were at the root of Ptolemy's geocentric theory. Briefly, he supposed that the sun revolved yearly in a small circle about the earth as centre. Each planet described a small circle (epicycle) about a point which itself revolved in a large circle (deferent) around the earth. The circular paths described by Mercury and Venus were interior to that of the sun, while the deferents for the remaining planets were exterior to the sun's path. The moon's path formed the smallest circle of all, and the epicycle motion was in the opposite direction to that of the other bodies. Beyond the deferent for the outermost planet, was the sphere of the fixed stars, and beyond this Ptolemy postulated the Primum Mobile. This latter furnished the motive force to turn the entire mechanism westward in the diurnal motion and to control the interior planetary motions. (Details of this system can be found in most standard textbooks on astronomy.)

The Ptolemaic system was virtually undisputed for thirteen centuries, and penetrated beyond the borders of science into the realms of literature[19] and religion.

It is of great importance to realize that both the Ptolemaic and Copernican theories explained the existent observations equally well. However, the latter system is much simpler, and has been amply verified and strengthened by subsequent developments since the sixteenth century.

While Ptolemy's theoretical considerations may have been restricted or prejudiced by Aristotelian philosophy, there can be no doubt concerning his own ability, initiative, and genius. It is obvious that Ptolemy will always be assured a unique place in the history of astronomy.

We appear to have gone a very long way from Greek thought—so far, perhaps, that we seem to be almost back again. Can it be that the progress of knowledge is like a Riemannian straight line, which, if produced indefinitely, will return upon itself? Such conjectures leave room for the cynical or nihilist inference that a

vacuous nothing, a mere nowhere, and a timeless never, are all (being nothing!) we can affirm.

However, even if astronomy may appear to be ending where it first began, the circuitous road in between bears true testimony to the remarkable progress of science, and, in particular, to the men of genius who marked the main turnings on that road. There can be no doubt whatsoever that Eudoxus of Cnidus, Heraclides of Pontus, Aristarchus of Samos, Hipparchus, and Ptolemy, all deserve to be recognized as illuminating sign-posts along the way.

Ottawa, January 1935.

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[11]*A commentary on the Phaenomena of Eudoxus and Aratus.*

[12]Probably a nova.

[13]R. S. Ball, *Great Astronomers* (Isbister), 1895.

[14]36″ of arc.

[15]When the stars could first be seen in the dawn after the sun had passed them in its annual motion.

[16]Sarton, G., *Introduction to the History of Science*, 1927, vol. I, p. 198.

[17]e.g., Nelson's Encyclopaedia.

[18]To the ancients the term meant any apparently hazy luminous spot in the heavens.

[19]e.g., the epic poems of Dante and Milton.

METEOR NEWS

Observations relating to meteors and meteorites are cordially invited.

Meteoric Research in the Soviet

Mention has been made in these pages on several occasions of the work of the Soviet astronomers in the field of meteoric astronomy. In Russia, the problems in this branch of the science perhaps form a more important part of the astronomical programme than they do in any other country engaged in active research. The writer is indebted to Dr. I. S. Astapowitsch, now of the Moscow Astronomical Institute, for the following interesting details.

Work on meteors is centred in Moscow where four organizations co-operate. These are the Association of Observers, the Moscow Astronomical Institute, the Meteor Section of the All-Union Astrogeodetic Society and the Meteorite Section of the Lomonossov Institute of the Academy of Sciences. The first two publish a *Bulletin* and a *Journal,* respectively. A regular seminar on meteoric astronomy was started this year and an annual colloquium on meteors has been held in March for the last three years. The First Union Conference on Comet and Meteoric Astronomy is planned in Moscow for the autumn of 1935.

Among the publications which have recently appeared, or are in course of preparation, are the following: "The Meteorites of the U.S.S.R." by Mr. L. A. Kulik, an account of some 80 Russian falls; studies of the origin of meteors by Prof. S. V. Orlov and Dr. Vsessviatsky; geometric methods for the reduction of observations by Mr. K. P. Stanjukowitsch; a study of telescopic meteors, a review of all Russian works on meteoric astronomy, and a study of the physics of the meteor by Dr. I. S. Astapowitsch. In addition, a co-operative work on meteor heights is being published in which it is shown that the generally adopted heights of meteors are too great by 15 or 20 per cent., owing to systematic errors of observation and reduction. A manual of meteoric astronomy has also been prepared for use in the university. It is unfortunate that the above works of importance are in Russian as this is a language that few astronomers

outside of the Soviet can read. It is to be hoped that very comprehensive summaries of all these publications will be made available in French, English or German. This would greatly advance the cause of international co-operation in meteoric research.

The Magnitude Distribution of Bright Meteors

One of the most important problems that confronts the student of meteors is the determination of the relative numbers of meteors of various intrinsic luminosities or, we may say, of various absolute magnitudes, where the latter term implies the magnitudes of the meteors when they are at some standard distance, such as 100 km. It is necessary to know this function when computing the total number of meteors that fall on the earth in a day, which in turn leads to an estimate of the mass of meteoric material in any given volume of space.

A few years ago the writer published a note[1] on the relative chances of photographing meteors at different altitudes. A simple law of absolute magnitude distribution was assumed, namely

$$\frac{N_{m+1}}{N_m} = x$$

where N_m is the number of meteors brighter than absolute magnitude m, and it was found that the relation between the frequency of photographic meteors and altitude depended greatly upon the value of x. Curves were drawn for $x = 3$, 4, and 5. If we compare an observed frequency curve with the computed ones we may obtain some idea of the actual value of x for bright meteors.

The best systematic series of observations to use in this connection is the A.I. series of Harvard patrol plates. In the period 1901 to 1930 approximately 28,000 exposures were made, the exposure time being as a rule one hour, though this was sometimes increased to two hours, and 92 meteors were photographed.[2] The lens, of six-inch focal length, was used at F16 or F6.8 up to 1929 and covered a field 60 degrees square. After 1929 it was used at F4. The relative numbers of meteors photographed at various altitudes are

[1] Proc. Nat. Ac. Sci., vol. 19, p. 34, 1933.

[2] W. J. Fisher, H. A., vol. 87, pt. 3, 1931.

of course greatly influenced by the number of exposures made at the various altitudes. To determine this an analysis was made of the altitude and azimuth at mid-exposure of 3200 A.I. plates taken in the three periods 1905-06, 1918-19, 1925-26. From these values the relative number of times the various altitudes had been covered was computed and, results for the three periods agreeing, mean values were found and assumed to hold for the entire interval 1901-1930. This is a valid procedure since exposures in this series were made according to a regular patrol schedule.

The altitude and azimuth of each of the 92 meteors photographed was computed. Below is listed, first, the actual number of meteors photographed in each altitude interval; and, second, the actual rela-

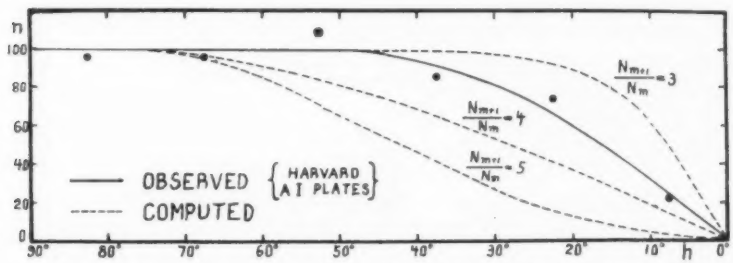


Fig. 1.—The frequency of photographic meteors "n" plotted against the altitude "h". N_m is the number of meteors brighter than absolute magnitude "m".

tive frequency of these meteors per unit area for different altitudes, found by applying the relative frequency of exposures covering each altitude. The units in this case are arbitrary, 100 corresponding approximately to one meteor photograph for each 300 hours of exposure time.

Altitude	*Meteors Photographed*	*True Relative Frequency*
0°—15°	1	22
15°—30°	12	74
30°—45°	19	86
45°—60°	34	108
60°—75°	19	96
75°—90°	7	96

These observed values of meteor frequency are plotted in Figure 1 together with the curves computed for $x = 3$, 4 and 5. It will be seen from inspection of this figure that x apparently lies in the neighbourhood of 3.5. In view of the camera used the faintest meteors photographed were probably of magnitude –2. We may then consider this survey to cover roughly the range of magnitudes –2 to –7 and to indicate the absolute magnitude distribution

$$\frac{N_{m+1}}{N_m} = 3 \cdot 5$$

for meteors in this range.

An analysis of azimuths instead of altitudes gave the relative frequency of bright meteors in each of the four quadrants. This is tabulated below.

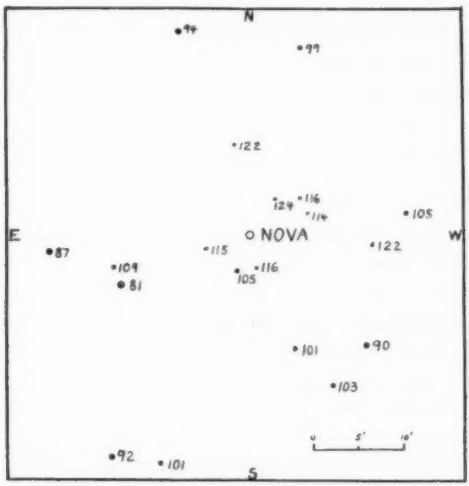
Quadrant	*Meteors Photographed*	*True Relative Frequency*
SW	38	7
NW	22	6
NE	10	4
SE	22	5

There seems to be some evidence here that bright meteors are more frequent in the southwest than in the northeast.

P.M.M.

NOVA HERCULIS

Nova Herculis has now become invisible to the naked eye but it should be carefully followed by those with telescopes. To aid in estimating its magnitude Dr. C. P. Gaposchkin, Dr. S. Gaposchkin and Dr. F. L. Whipple of the Harvard Observatory have accurately measured the photovisual magnitudes of the faint stars near Nova Herculis. These appear on Harvard Announcement Card No. 332.



FIELD OF NOVA HERCULIS, 1934.

The positions of the stars are plotted on the accompanying map. The photovisual magnitudes are given to the nearest tenth, the decimal point being omitted. Observations of Nova Herculis may be sent to the Dept. of Astronomy, University of Toronto, or to Mr. Leon Campbell, Harvard Observatory, Cambridge, Mass.

REVIEW OF PUBLICATIONS

A Finding List for Observers of Eclipsing Variables, by R. S. Dugan. 33 pages, 9 x 12 in. (Contributions from the Princeton University Observatory, No. 15).

The eclipsing variable fraternity of the world will welcome this valuable publication. It supplies a long-felt want of those observers who love to observe eclipsing variables, whether with the eye, photographic plate, photometer or spectrograph. The aim of the author was to supply a considerable amount of detailed information, which would enable the observer to understand what has been done, or is being done, on the variables, and thus to assist him in making out a worth-while programme. This aim has been splendidly accomplished.

The catalogue contains some 296 stars—those variables brighter than magnitude 13, and north of declination 30°S. which have fairly well-determined elements. Besides the usual data of the position, period, maximum magnitude, range, spectrum, depths of primary and secondary eclipses, duration of totality, etc., the author shows, by a liberal use of abbreviations and symbols, an amazing amount of information. The frequent use of a question mark indicates the existing uncertainty, and the need for further observations. A unique feature of the catalogue, and of particular interest to observers, are the columns wherein the desirability of further photometric or spectrographic observations is symbolically expressed.

The notes, which are on the opposite page to the photometric information, contain in compact form references to the published observations, identifications of the variable, comparison stars, recently observed minimum, etc., and remarks concerning the current observations. (If any of these remarks contain elements of hope and expectation, as the author suggests, his catalogue will help to accomplish the desired results).

For some years the author has kindly furnished to spectroscopic observers information from his carefully compiled card catalogue. He may perhaps have prepared his Finding List in self-defense, for

it certainly will eliminate the necessity of bothering him for some years to come. It is, however, a matter of great satisfaction that this pioneer observer of variable stars has published his catalogue, which will be helpful to all, and will stimulate further research.

J. A. P.

Lohse Tafeln für numerisches Rechnen mit Maschinen, neubearbeitet von P. V. Neugebauer; pp. 113, 6½ × 9½ inches. Leipzig: W. Engelmann, 1935. Price, RM 6.

The first edition of this volume of tables was compiled by Professor Lohse, of the Potsdam Astrophysical Observatory, in 1909, to facilitate computations by means of calculating machines. Professor Neugebauer, of the Recheninstitut in Berlin, in revising the volume for its second edition, has somewhat shortened it by the exclusion of the table of squares, and of formulae of trigonometry and calculus.

Of the present volume, the principal part, 91 pages, consists of a table of the trigonometrical functions, for each hundredth of a degree. This section has been copied photographically from the first edition. It is in general, though not uniformly, given to five significant figures. As all the six functions are listed side by side for each degree, the table is very convenient for use with a calculating machine.

The remainder of the book contains the reciprocals of the numbers from 1 to 5,000; a table for square roots; and tables for transforming from minutes and seconds of arc and of time to degrees and decimals of a degree. The latter auxiliary table is, of course, essential as long as we continue to use both the sexagesimal and decimal systems of angular measure.

The book is well bound, of a convenient size, and of small but very distinct type.

F.S.H.

Planetario Tascabile Hoepli, 1935. Price, 20 lire.

It is hard to describe this new planetarium. It contains 12 circular charts in duplicate of the celestial sphere reaching from pole to pole and extending over 10 h. of R.A., one of each pair showing the stars only, the other giving also the hour circles, the

declination circles and the names of the constellations. There are also 2 similar charts for the north and south polar regions. The charts are six inches across and are hinged along a diameter and fold into a simple cloth case held shut by a dome fastener. The whole slips easily into the pocket. Accompanying the planetarium is a 32-page booklet full of pictures and simple instructions for using the charts, with examples. The planetarium is adapted to all seasons and latitudes. It is cleverly designed and strongly constructed. Mr. Hoepli deserves high commendation for his services to astronomy, both in providing the Zeiss Planetarium at Milan and in issuing valuable astronomical publications.

C.A.C.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Why Red, Yellow and Green in the Aurora?

Mr. A. C. Berman, 5408 Esplanade Ave., Montreal, writes:

On the night of April 10 my friend Mr. Julius C. Greenblatt and I witnessed the most beautiful and impressive display of the aurora borealis we ever observed. It began at about 7.30 E.S.T. and except for a few intervals, lasted until midnight. The display started from the northeastern horizon and extended past the zenith; it appeared to have a "radiant point" in Mu Leonis. There were curtains, streamers, and all the other phenomena associated with a good display. There was one thing we could not explain and I submit this question to you. When the curtains were in progress there were three distinct layers, all parallel to the horizon. The lowest layer was reddish, the middle whitish and the highest greenish, and all blended into each other not unlike a continuous spectrum. Can you account for this phenomenon?

Dr. P. M. Millman, supplies the following information from a paper by L. Vegard, (Pub. Geoph. Inst., Oslo, v. 10, no. 4, 1933).

Apart from the oxygen green line 5577 and probably two oxygen lines in the red, 6301 and 6365, most of the light of the aurora is

given by the band spectrum of molecular nitrogen. A similar spectrum may be produced in the laboratory by letting cathode rays (negatively charged particles) fall on nitrogen, the rays having a velocity greater than that corresponding to 100 volts. Vegard concludes that the ordinary aurora is produced by cathode rays of about 1000 volts velocity falling on the upper atmosphere of the earth.

Vegard notes two types of red aurora, Type A, red all over; Type B, red at bottom edge of curtains.

Type A occurs at sun-spot maximum most frequently and its appearance is correlated very well with the occurrence of large sun-spots. The red colour is due to the enhancement of the red oxygen lines 6301 and 6365. These are apparently excited more easily by negative particles from sun-spots though the reason for this is not well determined.

Type B is very rare and occurs at sun-spot minimum. The red colour is produced by the enhancement of the first positive red bands of nitrogen and these are produced by highly penetrating negative rays that reach low altitudes and hence higher densities of nitrogen. This type of aurora appears at low altitudes, the height of the lower edge of the curtains being 70 km. in the only case measured. This is exceptionally low for the appearance of the aurora.

Sun-spot Activity

The demonstrated connection of sun-spots with terrestrial phenomena renders all trustworthy information regarding the sun's surface of great interest to the astronomer and the meteorologist. For many years the *Astronomische Mitteilungen* of the Federal Observatory in Zürich, Switzerland, have contained detailed reports on sun-spots and other solar phenomena. Communication No. 132, recently received, gives statistics for 1934 and a summary for previous years. The mean "relative-number" for 1934 is stated as 8.7 and the epoch of the last minimum as 1933.8. The epochs for the last five maxima are: 1883.9, 1894.1, 1906.4, 1917.6, 1928.4; and for the minima: 1889.6, 1901.7, 1913.6, 1923.6, 1933.8. The average length of the interval between these maxima is 11.56 years; between minima, 11.98 years. It will be worth while to observe any effect on radio reception as we pass through the coming sun-spot maximum.

Work at the Mount Wilson Observatory

The annual report of the director of this great observatory is full of interesting matters. It is hard to make a selection but the following extracts will illustrate some of the conclusions reached.

Sun-spots and Magnetic Polarities

The observations of polarities begun at Mount Wilson more than twenty years ago have in the past year again brought into prominence a remarkable phenomenon. With the appearance of spots of a new cycle, the prevailing sign of the magnetic field reverses. The average length of the cycle of sun-spot activity is 11.2 years, but the interval necessary to restore the original sign of the field is double this length. Since the discovery of the reversal of polarities by Hale in 1912, only one magnetic cycle has been completed, but its termination by the reversal shown by spots of the cycle just beginning now makes it certain that the behaviour of the magnetic fields is closely related to sun-spot activity and that the magnetic cycle of 22 or 23 years is equal in importance to that of sun-spot activity itself. The Mount Wilson observations of polarities afford the only existing material for the study of this fundamental problem.

The Surface of the Moon

Any attempt to study a body like the moon, of solid substance and without enveloping atmosphere, well illustrates the restrictions imposed when the spectroscope can not be used freely as in the case of gaseous bodies like the sun and the stars. Physical relationships with other members of the solar system are then difficult to trace. Nevertheless, something of the quality of the lunar surface can be learned from the polarization of the sunlight reflected by the moon, now being studied with a polariscope and Wollaston prism and a spectrograph. These measurements show that little or no solid rock is exposed and that the surface material consists of a highly porous substance like pumice, in agreement with the inference drawn from the very rapid cooling of the lunar surface which occurs when the supply of radiation from the sun is cut off. In addition, the total radiation received from the moon can be measured and resolved into its constituents. Measurements with a thermocouple at different phases over five lunations show almost complete symmetry around full moon in both the planetary heat and the reflected sunlight. The visual magnitude of the full moon calculated from these measures is –12.6, almost exactly midway between the sun and a star like Arcturus.

Atmospheres of Jupiter and Saturn

The identification of ammonia and methane in the atmospheres of Jupiter and Saturn goes far toward a complete explanation of the atmospheres of these planets. In the presence of the excess of hydrogen to be expected in such massive bodies, carbon, nitrogen and oxygen must have combined with

a part of the hydrogen as the planets cooled. Of the hydrocarbons, only methane, the most volatile of them all, has remained in gaseous form to show in the spectrum. Ammonia, more easily condensed, while abundant on Jupiter, as the observations show, should be relatively scarce on Saturn and probably absent from Uranus and Neptune. With an excess of hydrogen, the amount of ammonia observed on Jupiter would indicate a minimum temperature of about −123°C.

Physical Studies of the Stars

Here, as in the case of the sun, the most effective instrument is the spectroscope. The numerous spectrograms obtained for the determination of stellar distances are all available for a study of the radial motions and physical properties of individual stars. In addition, many others have been taken for special purposes. Several classes of variable stars and spectroscopic binaries have been studied, and the identification and behaviour of important groups of lines, especially in the near infra-red portion of the spectrum, have received much attention. For the first time, in the case of RS Ophiuchi, the lines of the solar corona have been recognized in the spectrum of a star, thus showing as might have been expected, that the elements and the physical conditions necessary for the appearance of these lines are not peculiar to the sun alone.

* * * * *

Observations of Nova Persei No. 2, 1901, show conclusively that the spectral phenomena of a nova are due mainly to an expanding shell of gas thrown out by the star. At the outer edge of the shell of nebulosity the emission lines are single; elsewhere they are double, owing to the motions of approach and recession of the portions of the shell nearest to and farthest from the observer, respectively. The maximum separation of the lines, appearing at points close to the star, corresponds to a relative velocity in the line of sight of nearly 2500 km. per second.

* * * * *

Continued measures of the red-shift of spectral lines, still interpreted provisionally as the result of receding motion, have revealed in the case of a faint nebula in the cluster Boötes No. 1 a probable velocity of 39,500 km. per sec., by far the largest known. The addition of velocities for thirty-five isolated nebulae to those already known has made it possible to test the velocity-distance relation, which was derived chiefly from clusters of nebulae. After allowing for the influence of selection on the magnitudes of the isolated nebulae, the agreement was excellent. Nine faint nebulae in the Virgo cluster give substantially the same mean velocity as other nebulae in the cluster averaging two magnitudes brighter, thus showing that within the interval covered the velocity does not depend on the luminosity of the nebulae.

AN ASTRONOMICAL FILM (*Contributed by F.T.S.*)

The motion picture film, "Looking Through Great Telescopes", shown at the Toronto Centre on April 2nd last inspires an amateur motion picture member of the Society to make a brief summary of this subject as it has impressed him to date.

Laboratory motion pictures of astronomy have been well done, as illustrated in "A Trip to the Moon", "The Satellites of Jupiter", showing their motion around the planet, and other cleverly faked phenomena. These have no doubt suggested the more ambitious film above mentioned. This latest film is (so far as this member could detect) practically in its entirety a genuine film, all the photographs being actually of the heavens themselves. Of course it is obvious the pictures were taken with a still camera through the great telescopes and afterwards pieced together in sequence to give the illusion of motion; but it was exceedingly well done, and must have taken much time and patience.

Some parts of the film were highly dramatic, for instance, the motion of an asteroid was shown passing along a field of fixed stars. No still photographic plate with the "trail" of an asteroid could equal this as a picture of what was taking place. The seeming "air flight" over the mountains and craters of the moon was also thrilling, and this illusion could be intensified in ways which could be suggested by one familiar with the mechanics of the "movies". The illusion could be made more perfect.

C.A.C.

MEETINGS OF THE SOCIETY

AT VICTORIA

February 20, 1935.—The meeting was held at 8 p.m. in the Y.W.C.A. Parlors. President Brydon was in the chair.

The following were elected to membership in the Society: Mrs. C. F. Swanell, Mr. A. J. Filmer, Mr. J. W. Pomeroy, Mr. Raymond Gravlin, Mr. H. P. Smith, Mr. Billy Reid.

The president then introduced the speaker of the evening, Mr. W. E. Harper, M.A., who spoke on "Calendar Revision". Big corporations who make comparisons of their business returns at stated times find the present calendar unsuitable for such purposes, because the months, quarter-years and half-years are of unequal length, and hence, it is impossible to compare a month this year which may have four Saturdays with the same month last year which might have five. The speaker declared, however, that calendar revision would meet with popular disapproval if it became too radical in wiping out cherished anniversaries, whether religious, domestic or national. Mr. Harper traced the origin of the calendar from the days of the ancient Egyptians to the present time. He referred to the proposed changes, the two main ones being the 13-month and 12-month schemes, but in the speaker's opinion if any reform were to be made he would favour that one making the quarter years of equal length.

April 13, 1935.—On this day thirty-three members and friends of the Victoria Centre, R.A.S.C., visited the Dominion Astrophysical Observatory on Little Saanich Mountain. At 7.30 p.m. they met outside the Y.W.C.A., as prearranged, and went out by chartered bus. The night was very clear and the view from the summit before entering the dome was well worth the trip. The half-moon near the zenith, with Mars to the south-east and Venus to the west made three brilliant celestial objects in the starry April sky. Dr. J. A. Pearce was in charge of the dome and in his genial way welcomed the members and gave descriptive talks, assisted by Mr. Robert Peters, on the three "viewings" of the evening, viz: the moon, Neptune with its moon, and gamma Virginis, the beautiful double in Virgo. Each member was allotted 30 seconds at the 7-inch refractor and then 30 seconds at the 72-inch reflector. A general feeling of appreciation of Victoria's happy proximity to the D.A.O. was noted. The easy availability of these instruments of precision with their astounding penetration into the depths of the cosmos, together with the Observatory's very courteous and helpful staff should be an inspiration to the activities of the R.A.S.C., Victoria Centre.

GORDON SHAW, *Secretary.*

AT TORONTO

March 12, 1935.—A regular meeting was held at 8.00 p.m., in the McLennan Laboratory of the University of Toronto; A. R. Hassard in the chair.

Three candidates were elected to membership in the Society, the last named being a member-at-large:

Miss Helen R. Shaw, Box 201, Richmond Hill, Ont.

Mr. Lawrence J. Hall, 286 Nelson Street, Sarnia, Ont.

Mr. R. Vernon Cook, Box 211, Pierceville, Kansas.

Four persons were proposed for membership.

Predictions of phenomena for the following two weeks were outlined by S. C. Brown. Recent observations were reported by A. R. Hassard, J. R. Collins and S. C. Brown. Answers to questions submitted at the previous meeting, referring to Dr. R. K. Young's lecture on "Planetary atmospheres" were prepared by Dr. P. M. Millman and read by Mr. J. R. Collins.

Dr. A. F. C. Stevenson, associate professor of applied mathematics in the University of Toronto, then spoke on "Simon Newcomb, his contributions to astronomy and mathematics". Born in Wallace, Nova Scotia, on March 12, 1835, the son of a pioneer school teacher, Newcomb received practically no regular education, although he attended his father's classes "when he felt so inclined". Mostly self-taught with the aid of inadequate textbooks, he showed an early interest in geology and astronomy. In spite of the fact that the family intended him to be a lawyer or a preacher, his first employment was with a "quack" doctor who professed to practise the botanic system of medicine. At the age of eighteen he decided to run away, probably the greatest decision of his life. His next vocation was that of a country school teacher in Maryland, during which time he made up his mind that mathematics was the subject which interested him most. At the age of 22 he became a computer in the Nautical Almanac office, then located in Cambridge, Mass. His contributions to mathematical astronomy started soon after and continued until the time of his death. In 1861 he was appointed a professor in astronomy at the U.S. Naval Observatory in Washington. It was in Washington, first at the Naval Observatory and later at the Nautical Almanac office, which was now removed to that city, that he did his best work. In 1875 he was offered the directorship of the Harvard College Observatory but declined, deciding to remain in the Naval Service. He became director of the Nautical Almanac office in 1877. For some years he also held the post of professor of astronomical mathematics in John Hopkins University. He was retired when he reached the age limit in 1897. Newcomb died on July 11, 1909, and was accorded a full military funeral in keeping with his rank as a rear-admiral by reason of his position as director of the Nautical Almanac office.

Newcomb was a most prolific writer, 541 works being recorded, of which a large number were important scientific papers. He was held in high regard as an economist. His books expounding science in popular words for the public have been translated into many languages. He also tried his hand at

novel writing. He showed a keen interest in the possibilities of flying. His mathematical researches, apart from astronomy, were mainly in the fields of probability and geometry, but the work upon which his reputation as a mathematician will undoubtedly rest are his contributions to celestial mechanics. Suspecting errors in the existing star-catalogues and nautical almanacs he decided to check them. The importance of such a work was evident. He made a careful survey in Europe to locate early records of observations of occultations upon which the tables of the moon's motions were based, and succeeded in greatly extending backwards the period of known observations of the moon's orbit, with the chief aim of improving the lunar theory.

Newcomb was a great astronomer; a man who attained the peak of his profession and the admiration of his colleagues, without influence and without any natural advantages other than his innate ability and his strength of character.

The thanks of the members and their friends were conveyed to Dr. Stevenson by Dr. A. T. DeLury and Mr. J. R. Collins. Dr. DeLury especially mentioned his meeting Professor Newcomb during the latter's visit to Canada at the time of the meeting of the American Association for the Advancement of Science.

March 26, 1935.—A regular meeting was held at the usual place and hour. J. R. Collins presided in the absence of the chairman.

Four candidates were elected to membership, the last named being a member-at-large:

Mr. W. R. Sherrick, 84 Benson Ave., Toronto 10.

Prof. A. F. C. Stevenson, M.A., Ph.D., Department of Applied Mathematics, University of Toronto.

Mr. Alan M. Vaughan, 14 Summerhill Gardens, Toronto.

Mr. G. Edward Pendray, 491 Westchester Ave., Crestwood, New York, U.S.A.

Prediction of phenomena for the following two weeks was outlined by F. L. Harvey.

Dr. A. P. Coleman, professor emeritus of geology in the University of Toronto, addressed the large audience on "Recurring ice ages; some personal experiences of a glaciologist during recent explorations". Dr. Coleman introduced his subject by mentioning that while other hobby enthusiasts were busy collecting stamps and such trifling objects, he had spent his time in "collecting" ice ages.

During the most recent ice age nearly all the glaciation occurred in North America and Eurasia, while, on the other hand, these were the two great areas which were almost entirely missed by the ice during the permocarboniferous age, at which time glaciation extended over the southern parts of the world and even far into the tropics.

Boulder clay and striated stones give positive evidence of the existence at one time of ice ages in South Africa, India, Australia and South America,

probably more than 250 million years ago. These countries which now have a warm, sub-tropical or tropical climate, definitely possessed, a geologically short time ago, an immense glaciation, the first indications of which were found in the tropical district of Central India. In that country, well within the tropics, where to-day the natives dress very sparingly because of the intense heat, there was once an ice cover several thousand feet thick. The same was true in South America where to-day one finds the rank vegetation of the tropical jungle within a mile of Rio de Janeiro.

The oldest ice age of which we have positive proof is found in Canada, near Cobalt, Ontario, and occurred about 800 million years ago.

Dr. Coleman left this "poser" with the astronomers present, with a suggestion that they might provide a solution. "The earth from a geologist's point of view cannot be a slowly cooling sphere. The temperature has been going up and down for millions of years. Why is it that the most tremendous of these ice ages occurred immediately after the most intense period of heat and tropical growth of which we have any record?"

In reply to a question from a member as to the possibility of future ice ages, Dr. Coleman explained that in his opinion we are now living in an interglacial age; that it will get warmer for perhaps 50,000 years and then in about 100,000 years it will be much colder again. "I am quite sure that the ice will come back," he concluded.

Dr. Coleman's lecture was exceptionally well illustrated with lantern slides, not only of the inevitable results of ice action, boulder clay and striated stones, but also of the present native fauna and flora of the countries which he had visited and of scenes taken on the way. Practically every slide which was shown had been hand-coloured by the speaker himself, who enjoys an enviable reputation as an artist as well as a geologist.

A vote of thanks was moved by R. A. Gray, who himself had accompanied Dr. Coleman on geological field-trips in Western Canada, and seconded by S. C. Brown. Sir Frederic Stupart also expressed his appreciation of the lecture.

FREDERIC L. TROYER, *Recorder.*

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